Silvical Characteristics of Balsam Fir

(Abies balsamea)

by Arthur C. Hart

Preface

MUCH of the silvical information on our forest trees is widely scattered and sometimes difficult to find. To make this material more readily available, the Forest Service is assembling information on the silvical characteristics of all the important native forest tree species of the United States. It is expected that this information will be published as a comprehensive silvics manual.

This report presents the silvical characteristics of one species. It contains the essential information that will appear in the general manual but has been written with particular reference to the species in the Northeast. Similar reports on other species are being prepared by this Experiment Station, and by several of the other regional forest experiment stations.

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About the Author ...

ARTHUR C. HART, *research forester, has spent most of his professional career in the spruce-fir region of the Northeast. After taking his Bachelor's degree in forestry at the University of Connecticut in 1936 and his Master's at the Yale School of Forestry in 1938, he joined the Northeastern Forest Experiment Station and did research work at Alfred, Maine, and Gale River Experimental Forest at Bethlehem, N.H. He left Federal service in 1941 to become manager for the Great Mt. Forest at Norfolk, Conn., then served as senior forester with the Exploration Division of the Rubber Development Corporation in Brazil and later with the Corps of Engineers at the American Cinchona Plantation in Costa Rica. Hart returned to the Northeastern Station in 1946, and since then has been engaged in research in the spruce-fir type at the Gale River Forest and for the past 10 years at the Station's research center at Bangor, Maine.*

The Balsam Fir

BALSAM fir takes its name from the Latin word for balm. Some people know the tree as the Balm-of-Gilead fir. It has also been called the blister fir, because of the bark blisters that yield Canada balsam, a resin that is used for, among other things, mounting microscope slides. The needles of balsam fir have a spicy aroma that Donald Culross Peattie has called "the dearest odor of all Nature".

Balsam fir *(Abies balsamea* (L) Mill.) is a small to medium-size tree of the Boreal and Northern Forest Regions of eastern North America (fig. 1). It occurs in Canada from Labrador, Newfoundland, and Nova Scotia through New Brunswick, Quebec, Ontario, and the Prairie Provinces northwest to Lesser Slave Lake and the Athabaska River in Alberta *(11, 17, 38).* In the United States its range extends south into Minnesota, Wisconsin, Michigan, northern Pennsylvania, New York, and the New England States (fig. 2). The tree also occurs locally in Virginia, West Virginia, northeastern Iowa, and southeastern Minnesota *(19, 25).*

Fraser fir *(Abies fraseri* (Pursh) Poir), which is found at elevations above 4,000 feet in the southern Appalachians, is similar to balsam fir in many respects and sometimes goes under the same common name. However, as a distinct species, it is outside the scope of this report.

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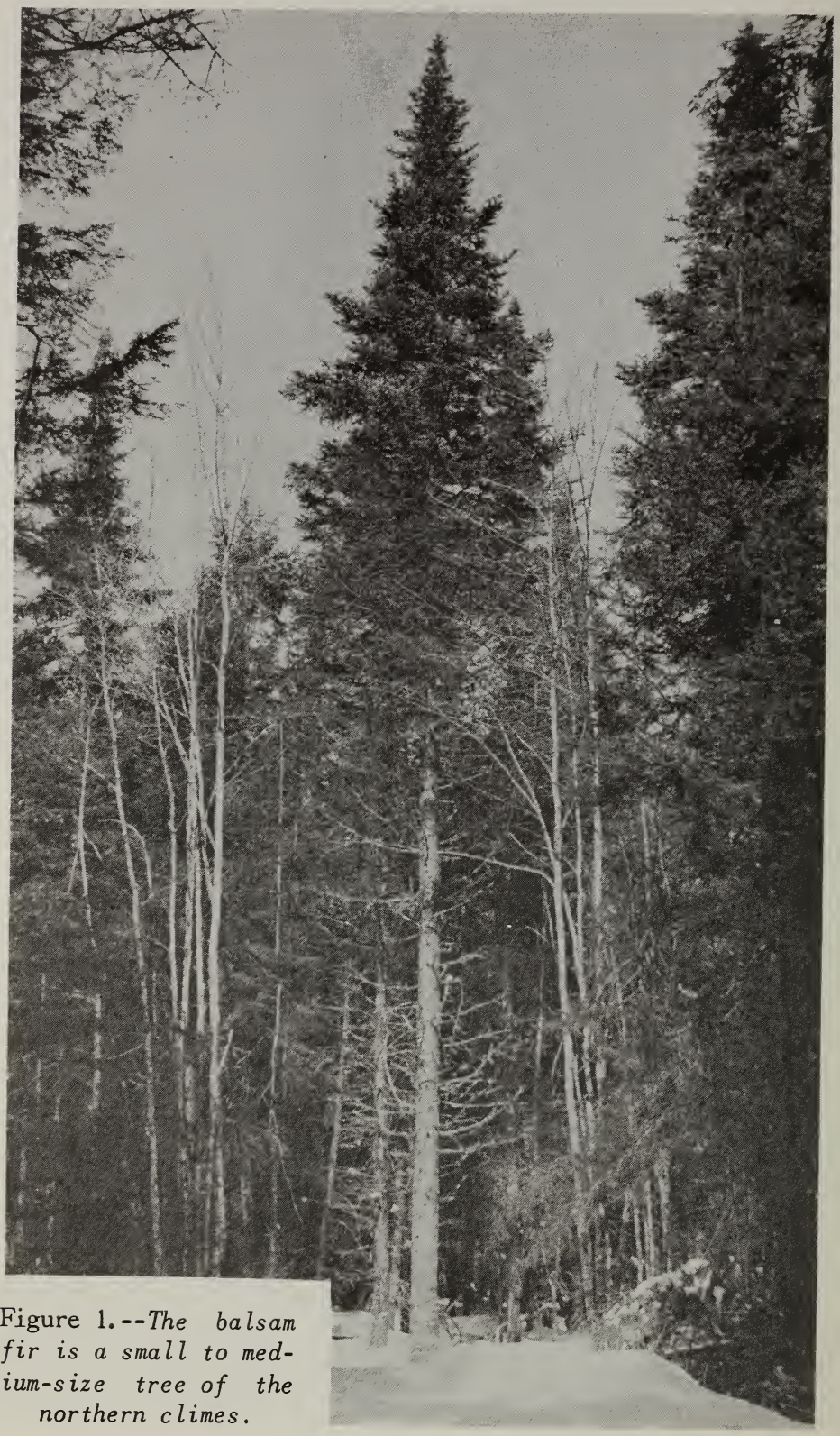

Figure 1.--*The balsam fir is a small to medium-size tree of the northern climes.*

Habitat Conditions

CLIMATIC

Balsam fir requires a cold climate and abundant moisture. It reaches its best development in southeastern Canada and northeastern United States *(16)*. A mean annual precipitation of 30 inches or more, well distributed throughout the year, with average summer temperatures of 70°F. or less, appears necessary for its best development *(17, 58)*.

The average annual temperature over the range of balsam fir varies from 35° to 50°F. The average temperature for January varies from 0 to 35°; for July from 65° to 70°. The average maximum is 90° to 95° and the average minimum is 0 to -40°. The highest temperature on record is 100° and the lowest is -50°. The frost-free period varies from 80 to 180 days *(46)*, and average annual precipitation from 10 to 50 inches *(17, 46)*.

Figure 2.--*The natural range of balsam fir.*

SOILS

Balsam fir will grow on many different types of soil and over a wide range of drainage conditions. Most of the soils fall into the broad groups of podzol, podzolic, gray wooded, or glei soils *(33, 39, 54, 55, 56),* from pH 4.0 to 6.0 in reaction. They range from silt loams developed from lacustrine deposits to stony loams derived from glacial till. Fir will also grow--but comparatively slowly--on gravelly sands and in peat swamps. The best development of individual trees occurs where soils are deep and well drained yet abundantly supplied with moisture *(18).*

PHYSIOGRAPHIC

Balsam fir grows from near sea level in Maine and southeastern Canada to timberline at approximately 5,600 feet in the Appalachian Mountains. Toward the western part of the range, from James Bay and Lake Superior to the Athabaska River in Alberta, balsam fir stands become increasingly scattered and more restricted to stream valleys and north-facing slopes *(17).*

BIOTIC

Balsam fir is one of the major species of the northeastern United States and southeastern Canada. It is a major component of seven forest cover types recognized by the Society of American Foresters *(43)* and a minor component of sixteen. The cover types of which it is a major component are:

Type 4--White spruce-balsam fir
Type 5--Balsam fir
Type 7--Black spruce-balsam fir
Type 9--White spruce-balsam fir-aspen
Type 33--Red spruce-balsam fir
Type 35--Paper birch-red spruce-balsam fir
Type 36--White spruce-balsam fir-paper birch

Balsam fir occurs in pure stands on low-lying moist flats (fig. 3), in swamps, and on upper slopes. It also occurs mixed with the following species:

In The Boreal Zone

Black spruce	*(Picea mariana)*
White spruce	*(P. glauca)*
Paper birch	*(Beula papyrifera)*

Figure 3.--*On low-lying moist flats, balsam fir occurs in pure stands. This dense second-growth stand is in central Maine.*

In the Northern Forest

White spruce	*(Picea glauca)*
Paper birch	*(Betula papyrifera)*
Beech	*(Fagus grandifolia)*
Quaking aspen	*(Populus tremuloides)*
Bigtooth aspen	*(P. grandidentata)*
Red spruce	*(Picea rubens)*
Yellow birch	*(Betula alleghaniensis)*
Red maple	*(Acer rubrum)*
Eastern hemlock	*(Tsuga canadensis)*
Eastern white pine	*(Pinus strobus)*
Jack pine	*(P. banksiana)*

In Swamps

Black spruce	*(Picea mariana)*
Tamarack	*(Larix laricina)*
Red maple	*(Acer rubrum)*
Black ash	*(Fraxinus nigra)*
Northern white-cedar	*(Thuja occidentalis)*

Shrubs associated with balsam fir include:

Beaked hazelnut	*(Corylus cornuta)*
Speckled alder	*(Alnus rugosa)*
Hazel alder	*(A. serrulata)*
Red-osier dogwood	*(Cornus stolonifera)*
Witch hobble	*(Viburnum alnifolium)*
Highbush cranberry	*(V. trilobum)*
Squashberry	*(V. edule)*
Striped maple	*(Acer pensylvanicum)*
Mountain maple	*(A. spicatum)*
Mountain ash	*(Sorbus americana and S. decora)*
Low bush blueberry	*(Vaccinium angustifoloum)*
Labrador tea	*(Ledum groenlandicum)*
Sheep laurel	*(Kalmia angustifolium)*
Red raspberry	*(Rubus idaeus)*

Some of the more common associated herbs are:

Bunchberry	*(Cornus canadensis)*
Wood sorrel	*(Oxalis acetosella)*
Canada mayflower	*(Mianthemum canadensis)*
Creeping snowberry	*(Chiogenes hispidula)*
Clintonia	*(Clintonia borealis)*
Golden rod	*(Solidago macrophylla)*
Star flower	*(Trientalis americana)*

Wild sarsaparilla	*(Aralia nudicaulis)*
Violet	*(Viola incognita)*
Twisted stalk	*(Streptopus amplexifolius)*

Mosses associated with balsam fir include species of *Sphagnum, Hylocomium, Hypnum, Dicranum, and Polytrichum.*

Certain associations of these mosses, herbs, and shrubs have been shown to indicate forest site quality *(21, 49, 50, 52).* The four main indicator associations, designated as *Hylocomium-Hypnum, Cornus-Maianthemum, Oxalis-Cornus,* and *Viburnum-Oxalis,* respectively indicate increasing productivity of site and increasing proportions of hardwoods in natural stands; only the *Hylocomium-Hypnum* sites are likely to be occupied by pure balsam fir.

Balsam fir provides food and cover for numerous animals and birds. Browsers include moose *(Alces americana)* and white-tailed deer *(Odocoileus virginianus),* although fir is regarded as an emergency food for deer *(35).* Ruffed grouse *(Bonasa umbellus)* and red squirrels *(Sciurus hudsonicus)* feed upon the buds and seeds *(18, 5);* various mice and songbirds eat the seeds; and porcupines *(Erethizon dorsatum)* feed upon the bark (26).

Other associated animals include the varying hare *(Lepus americanua),* marten *(Martes americana),* fisher *(M. pennanti),* red fox *(Vulpes fulva),* lynx *(Lynx canadensis),* bobcat *(L. rufus),* wolverine *(Gulo luscus),* woodland caribou *(Rangifer caribou,* and black bear *(Euarctos americanus).*

Bears frequently damage fir trees in northern Maine by stripping off the bark in early spring *(57).* Upon emerging from hibernation, bears tear off the bark, apparently licking a "spring tonic" from the moist inner bark and exposed sapwood.

Life History

SEEDING HABITS

Flowering and Fruiting

Both male and female flowers develop from buds formed the previous summer. Male flowers are borne in the axils of needles on the undersides of shoots. Female flowers occur on the upper side of shoots. In a 3-year study of flowering on over 1,000 co-dominant balsam fir trees in dense even-aged stands on the Green River Watershed in New Brunswick, male flowers averaged 22 per flower-

ing shoot; female flowers 1 to 3 per shoot *(31)*. Flower buds usually open the last of May or early in June before the vegetative buds. Female flowers occur mostly in the top 4 or 5 feet of the crown and male flowers in the next 10 feet below. Flower production is best on the outer ends of branches where light intensity is greatest *(31)*.

The fruit is an erect cone 2 to 4 inches long with thin, closely overlapping scales (fig. 4). The cone matures and ripens the first fall, and the scales drop away from the central axis with the seeds.

Seed Production

Seed production may begin when trees are 15 years old *(41)*, although good production usually does not begin until after 30 years of age. Dominant and co-dominant trees produce the most cones, with open dominants having better production than those that are crowded *(31)*.

Good seed crops occur every 2 to 4 years. Light crops usually occur during intervening years. A bushel of cones weighs approximately 35 pounds and will produce from 37 to 42 ounces of clean seed. The number of seeds per pound ranges from 30,000 to 94,500, with an average of 59,800 *(47)*.

Balsam fir seeds have dormant embryos and should be stratified in moist sand at 41°F. for 90 to 240 days before planting to break their dormancy *(47)*.

Figure 4.--*The cones of balsam fir.*

Seed Dissemination

Seedfall begins in late August or early September and continues throughout the fall and winter to early spring. Most of the seed is spread by wind, a maximum distance of about 8 chains (528 feet). The effective distance is much less, however, and many seeds falling with the cone scales land close to the base of the tree *(42)*. Seed is also spread to some extent by rodents *(47)*.

VEGETATIVE PROPAGATION

Layering is not an important means of regeneration, yet lower branches of balsam fir may layer when in contact with moist soil *(42)*. Live branches left on the stump after cutting will develop into new trees; and Christmas-tree growers utilize this principle in growing "turnups" *(8)*. The species grafts without difficulty, and horticulturists sometimes graft other firs to balsam fir rootstocks. However, no reports were found of balsam fir itself having been propagated either by grafting or by cuttings.

SEEDLING DEVELOPMENT

Germination of commercial lots of balsam fir seed has been reported to range from 1 to 74 percent, with an average of 22 percent *(47)*. This low viability may be due to seed injury during the dewinging process *(40)*.

With favorable seedbed conditions, most germination occurs from late May to early July. Adequate moisture is the chief controlling factor. Almost any type of seedbed--mineral soil, rotten wood, or shallow duff--will do for balsam fir if enough moisture is present. Thick duff is less favorable, probably because the surface dries out quickly. There may be some delayed germination on thick duff in August, but comparatively few seedlings become established. When the combined thickness of the L and F layers exceeds 3 inches, establishment usually is very poor *(36)*. In general, the closer the seeds lie to mineral soil, the greater will be the initial establishment of seedlings.

Germination and initial establishment are best under cover, with seedlings becoming established wherever the minimum light intensity averages from 15 to 20 percent or more of full sunlight at noon *(36)*. Those starting in the open undergo heavy initial mortality because of high surface temperatures, drought, and frost-heaving *(29, 36)*. However, few losses occur in the open after the first year, and the seedlings that survive grow better in the open than those under shade.

Figure 5.--*Balsam fir reproduction needs nearly full light for best development. These vigorous young trees became established in an opening after a logging operation in central Maine.*

Balsam fir seedlings have longer tap roots and have a better chance of reaching a permanent moisture supply than spruce seedlings. Nevertheless, many fir seedlings that germinate after the first week of July may die during dry summer weather *(36)*.

Winter mortality is caused by frost-heaving and the smothering or crushing of seedlings by litter, ice, and snow. Hardwood leaves are the greatest hazard in mixed stands.

Once the balsam fir seedling has become established, its early growth is determined largely by the amount and character of overhead competition. Dense growths of bracken, raspberry, and hardwood sprouts--especially maples--are the chief competitors on heavily cut-over lands in the northeast *(48)*.

Balsam fir will grow well in dense shade during the first 6 or 8 years of its life. Thereafter, it will live under dense cover for a long time. But it needs nearly full light for best development (fig. 5). The tree will respond quickly to release *(16, 34, 48)*.

Dense, even-aged balsam fir stands may not reproduce themselves if clear-cut. Some type of partial cutting is recommended to open up these stands and let in enough light to enable reproduction to become established. In mature and more open stands, and in all-aged stands, conditions are more favorable for regeneration. Usually advance reproduction is already established. In these stands, any type of cutting will probably result in another crop of balsam fir.

Balsam fir tends to increase in proportion to red spruce in second-growth stands. This is probably due to the larger seed, more frequent seed years, easier establishment, more robust seedlings, and faster early growth of balsam fir.

Temperature seems to be the most important climatic factor in controlling the beginning and rapidity of height growth; a temperature of at least 50°F. is required to start growth *(4)*. Height growth has been observed starting on May 27 and May 26 respectively at Keene, New Hampshire *(24)*, and at the Upper Peninsula Experimental Forest in northern Michigan[1]; respective termination dates were July 23 and August 23. At Keene, fir started growth later and ended growth earlier than most other species. Radial growth is reported to start May 26 and May 18, respectively, in Ontario *(7)* and at the Upper Peninsula Experimental Forest, and to terminate August 30 and September 6.

SAPLING STAGE TO MATURITY

Growth and Yield

Balsam fir is a small to medium-size tree at maturity, reaching 12 to 18 inches in diameter and 40 to 60 feet in height *(18)*. Maximum size is reported to be 34 inches by 75 feet *(1)* and maximum age about 200 years *(30)*. A tree 25.4 inches by 77 feet cut in

[1]Phenological data from U. S. Forest Service Lake States Forest Expt. Sta.

1948 on the Green Mountain National Forest near Danby, Vermont, was said by Marinus Westveld[2] to be the largest living balsam fir he had ever seen. This tree contained 77.2 cubic feet of gross volume from a 2-foot stump to a 4.2-inch top diameter inside bark. Cull due to butt rot reduced the net volume to 43.2 cubic feet of sound wood, equivalent to the volume of a sound 19-inch tree.

The branches on balsam fir are in whorls of 4 or 5, with scattered branches between whorls. In stands of mature trees, most new shoots are produced in the top 15 feet of crown *(32)*. Quantity of foliage per acre probably reaches its peak when stands are about 55 years old, then declines. During flowering years, growth of primary branch terminals and leaders is depressed *(31)*. Needles persist for 8 to 13 years *(58)*. Needle fall takes place during autumn and winter.

Bark thickness is seldom more than 0.7 inch at stump height, or 0.3 inch at a 4-inch top diameter. Bark volume is about 10.5 percent of the whole tree volume *(58)*.

Growth of balsam fir is related to vigor and crown ratio (proportion of total tree height in live crown). A study in Maine[3] showed that high-vigor fir with a crown ratio of 0.7 or better averaged 2.4 inches of diameter growth in 10 years. Growth rates for smaller crown ratios and less vigouous trees ranged down to an average of 0.4 inches in 10 years for low-vigor trees having crown ratios of 0.4 or smaller. Vigorous trees given room to grow will reach 10 inches in diameter and 50 to 60 feet in height in about 50 years.

Yields per acre in total cubic-foot volume, including stump and top, of all trees above 0.6 inch d.b.h. are given by Meyer *(28)* as follows:

Age (years)	*Site index*			
	70	*60*	*50*	*40*
20	165	135	110	80
30	1,455	1,210	960	720
40	3,940	3,270	2,600	1,940
50	5,910	4,920	3,920	2,910
60	7,100	5,900	4,700	3,500
70	7,760	6,450	5,140	3,820
80	8,270	6,870	5,480	4,080
90	8,700	7,230	5,760	4,290

[2]Marinus Westveld, U. S. Forest Service silviculturist, who devoted most of his professional career to studies of the spruce-fir forests of the Northeast, is a leading authority on the silviculture of this forest type. He retired in 1952.

[3]McLintock, Thomas F. A tree classification for red spruce and balsam fir. Unpublished manuscript, Northeast. Forest Expt. Sta., 33 pp., illus. 1953.

These yields were calculated from sample plots in pure, even-aged spruce-fir stands, mostly on old fields. They tend to exaggerate the yields that might be expected from irregular stands such as develop after cutting. Empirical yield tables for the Northeast by Westveld *(51)* take into consideration stand density, composition, and time since cutting. They give merchantable volume of spruce and fir combined in trees 6 inches d.b.h. and up from a 1-foot stump to a 3-inch top diameter inside bark. The following tabulation from Westveld shows, for different stand densities and different ages since cutting, the yields in cubic feet of merchantable volume in stands on dominant softwood sites where 90 percent or more of the trees are spruce and fir:

Age since cutting (years)	Density index (regional average - 100)		
	50	100	150
10	245	349	422
20	425	539	618
30	622	743	828
40	830	961	1,049
50	1,054	1,187	1,281

Reaction to Competition

Balsam fir is classified as very tolerant *(2)*. Some authors rate it more tolerant and others less tolerant than red spruce. However, the relative tolerance may vary with soil fertility and climate *(36)*.

The chief competition comes from heavy-shade producing hardwoods like beech and maple. Competition from aspen, birch, and other thin-crowned species is not so severe. Balsam fir growing in pure stands usually expresses dominance but frequently occurs in dense thickets where it suffers from heavy competition with itself (fig. 6).

In New England, balsam fir is considered a subclimax type, except that it may be a climax in the zone below timberline. It tends toward a climax in Quebec and in the Lake States *(43, 15)*.

Susceptibility to Fire, Wind, Frost, and Pests

Because of their thin bark, shallow root system, and inflammable needles, balsam firs of all ages and sizes are easily killed by fire. Fir is also subject to windfall, especially on shallow, wet soils: trees in the 8-inch d.b.h. class and larger and trees over 50 years old are highly susceptible *(27, 45)*.

Figure 6.--*In many places, balsam fir grows in dense thickets, and here growth is very poor. This fir thicket in central Maine is about 40 years old.*

Late spring frosts cause the death of tender, succulent needles and shoots of the current season *(10)*. However, fir buds are less sensitive to winter drying than those of red spruce *(14)*.

Balsam fir has several insect enemies *(13)*. The two most important now are the spruce budworm *(Choristoneura fumiferana)* and the balsam woolly aphid *(Adelges piceae)*. The spruce budworm, which, despite its name, prefers fir to spruce, is most likely to cause heavy damage in stands that contain mature fir, a dense stocking of fir, or a high proportion of fir in relation to other species. This insect feeds upon fir needles, and if a tree loses enough needles it dies. Vast budworm outbreaks in Canada, Maine, and the Lake States have killed millions of cords of balsam fir.

The balsam woolly aphid is an introduced insect that is becoming increasingly more important in the northeastern United States and southeastern Canada. This is a sucking insect. The salivary injections by the aphids kill or deform fir trees.

The insect first attacks individual trees and later spreads to trees nearby. Unless checked by low winter temperatures, the

populations build up and kill or weaken many trees by stem attack. Severe stem attack may kill trees within 3 years. The aphid also attacks twigs and buds, causing gout-like swellings, followed by gradual dieback of the twigs and of the tree tops as a whole. Reproduction, as well as larger trees, may be severely damaged. An abnormal growth of the tracheids caused by a substance in the insect saliva results in a dark, brittle type of wood called "red-wood" *(3).*

The eastern hemlock looper *(Lambdina fiscellaria fiscellaria)* and the black-headed budworm *(Acleris variana)* are also serious defoliators of balsam fir at times.

The balsam fir seed chalcid *(Megastigmus specularis)* destroys a high percentage of balsam fir seed. Seed losses of 22 to 57 percent may occur and could be responsible for the low germinating capacity of balsam fir seeds. Normal and infested seeds cannot be separated visually *(20).*

Nine fungi cause most of the decay in living balsam fir trees *(6).* One of these, *Stereum sanguinolentum,* which causes trunk or top rot, enters the tree through stubs, spike tops, and broken tops and is responsible for two or three times the cull losses caused by butt rots.

White stringy butt rot is caused by *Corticium galactinum, Odontia bicolor, Poria subacida, Armillaria mellea,* and *Omphalia campanella.* Brown cubical butt rot is caused by *Coniophora puteana, Polyporus balsameus,* and *Merulius himantioides.* These fungi all enter the tree by way of the roots or through basal wounds.

Although the butt rots are not responsible for an excessive amount of cull in standing trees, they do weaken the trees and make them more susceptible to wind damage. This defect is so serious that it is the decisive factor in setting the age at which a fir stand should be harvested--70 years *(44).*

Rot may develop as early as 40 years and increases as trees get older. More than half of all trees are generally infected at 70 years of age. There is no known reliable external indicator of rot, and even fruiting bodies are rare on living trees. Site seems to have an effect on the incidence and severity of rot; generally the drier the site, the greater the damage from rot *(6, 22, 23).*

The shoestring fungus, *Armillaria mellea,* listed above among the butt-rotters, also causes a root rot that results in some mortality *(53).* A canker and dieback caused by a species of *Nectria* has been reported to kill balsam fir in Ontario *(37).*

Special Features

Resin blisters on the bark of the trunk of balsam fir (fig. 7) yield an oleoresin used in the manufacture of medicinal compounds and varnish, as a mounting medium in the preparation of microscopic slides, and for cementing lenses in optical instruments *(18)*.

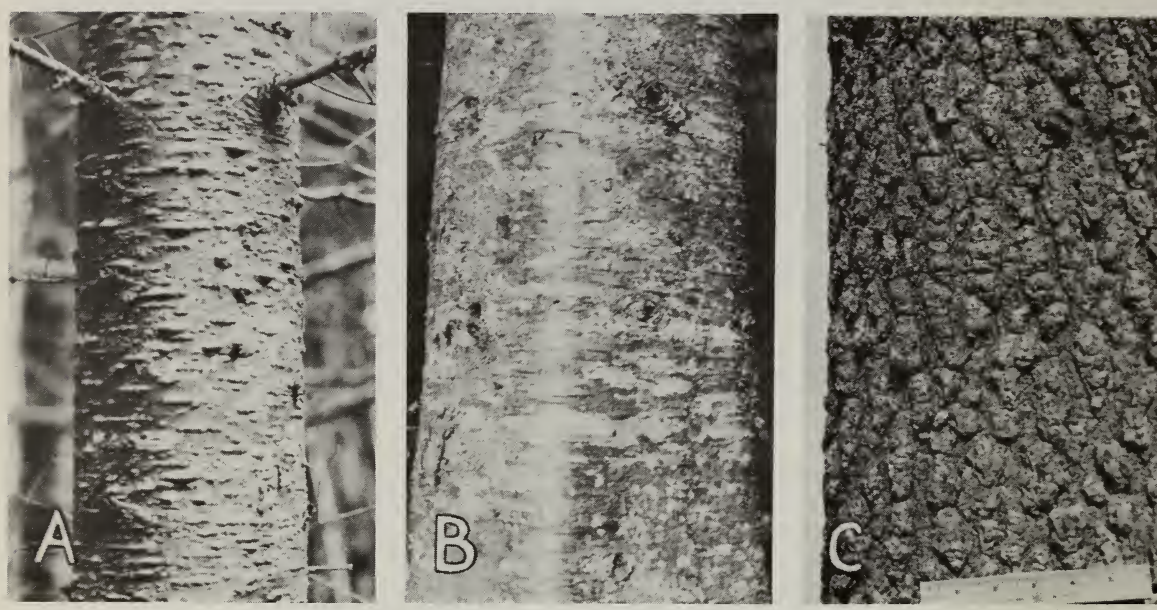

Figure 7.--*Characteristics of balsam fir bark.* A, *a young tree, showing resin blisters.* B *shows the bark of a mature tree,* C *an old tree.*

Balsam fir is highly prized as a Christmas tree because of its fragrance, good form, and exceptionally long needle retention after being cut *(12)*. Also, cut branches are used for Christmas wreaths. For this purpose foliage that has grown in the shade is preferred; it is characterized by relatively long, flat, blunt needles that tend to spread in a horizontal plane along the twig. In foliage that grew in sunlight, the needles often are curved, may be sharp or blunt, and spread from the twig on all sides in a spiral arrangement *(9)*.

The fragrance of balsam fir needles accounts for another distinctive minor use--as stuffing for souvenir pillows *(12)*.

Races and Hybrids

No distinct geographic races of balsam fir have been identified. Two botanical varieties are recognized: *Abies balsamea* var. *balsamea*, described above; and *A. balsamea* var. *phanerolepis* Fern., distinguished by having cone scales shorter than the bracts, which is found infrequently from Labrador and Newfoundland to Maine and Ontario, in the high mountains of New Hampshire, Vermont, and New York, and locally in northern Virginia and West Virginia *(25)*.

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